

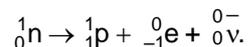
TAP 535- 3: Things that don't change

Checking on conserved quantities

Try these questions, which require you to notice quantities that are conserved.

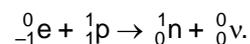
Change, and no change

Here is the equation for the reaction in which a neutron decays to a proton p, an electron e and an antineutrino $\bar{\nu}$:



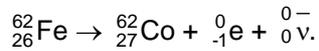
1. How does the equation show that the total number of nucleons remains the same?
2. How does the equation show that the total electric charge remains the same?
3. Which symbols show that the electron and antineutrino are not nucleons, but leptons with zero nucleon number?
4. An electron is a lepton. An antineutrino is an antilepton. Explain how in this reaction the lepton number is conserved, even though it creates two leptons.

Here is the equation for an electron interacting with a proton to produce a neutron and a neutrino:



5. How does the equation show that the total number of nucleons remains the same?
6. How does the equation show that the total electric charge remains the same?
7. How does the equation show that the total lepton number remains the same? Why is this neutrino not an antineutrino?

The stable iron nucleus is ${}_{26}^{56}\text{Fe}$; 'lightweight' iron ${}_{26}^{49}\text{Fe}$ decays emitting a positron and a neutrino. 'Heavyweight' iron ${}_{26}^{62}\text{Fe}$ decays emitting an electron and an antineutrino. Here are the reactions:



8. In the first equation, what values show that the nucleon number stays the same?

9. In the second equation, what values show that the nucleon number stays the same?

10. How can you see from the first equation that charge is conserved?

11. How can you see from the second equation that charge is conserved?

12. In the first equation, the positive electron (positron) is an antilepton. How does the equation show that total lepton number is unchanged even though two are produced?

13. In the second equation, why is an antineutrino emitted?

14. In both equations, how does the reaction change the chemical element involved?

Practical advice

These are intended as simple practice questions, on conservation principles for particles. The most difficult point is that an antielectron plus a neutrino or an electron plus an antineutrino do not change the total number of leptons (a lepton and an antilepton in each case).

Social and human context

Particle physics involves creating meaningful categories, such as 'lepton' and 'nucleon', to form families. These come from thought, not 'directly' from experiment.

Answers and worked solutions

1. The upper numbers (nucleon number) add up to the same on the left and right:
 $1 = 1 + 0 + 0.$
2. The lower numbers (charge number) add up to the same on the left and right:
 $0 = 1 + (-1) + 0.$
3. The upper (nucleon) number is zero for both (even though an electron has some mass).
4. The reaction produces one lepton and one antilepton. The electron has lepton number 1. The antineutrino has lepton number -1 . Together, they add to zero. The total lepton number is zero before and after.
5. The upper numbers (nucleon number) add up to the same on the left and right:
 $0 + 1 = 1 + 0.$
6. The lower numbers (charge number) add up to the same on the left and right:
 $-1 + 1 = 0 + 0.$
7. An electron (a lepton) vanishes on the left. A neutrino (also a lepton) is created on the right. The total lepton number remains equal to 1. If the neutrino were an antineutrino the lepton number would go from $+1$ to -1 , and not be conserved.
8. The total nucleon number 49 remains constant: $49 = 49 + 0 + 0.$
9. The total nucleon number 62 remains constant: $62 = 62 + 0 + 0.$
10. The electric charge on the nucleus is decreased, the charge being carried away by the positron: $26 = 25 + 1 + 0.$
11. The positive electric charge on the nucleus increases, a negative charge being carried away by the electron: $26 = 27 + (-1) + 0.$
12. A lepton–antilepton pair is produced, so the lepton number does not change.
13. The antineutrino 'cancels' the increase in lepton number due to producing an electron.
14. The charge on the nucleus changes. So the number of electrons around the nucleus changes, altering the chemical properties of the atom

External reference

This activity is taken from Advancing Physics chapter 17, 10S